# CLAIMS

What is claimed is:

1. A system for balancing state of charge among plural series connected electrical energy storage units, comprising:

   a string of electrical energy storage units, each storage unit having a state of charge;

   a circuit selectively monitoring the state of charge of each storage unit; and

   when the state of charge of a selected unit is greater than a target state of charge, the circuit transferring energy from the selected unit to the string of storage units, such that the state of charge of the selected unit converges toward the target state of charge.

2. The system of claim 1 wherein:

   when the state of charge of the selected unit is less than the target state of charge, the circuit transferring energy from the string of storage units to the selected unit, such that the state of charge of the selected unit converges toward the target state of charge.

3. The system of claim 1, wherein the circuit comprises:

   a power converter;

   the power converter transferring energy from the selected unit to charge the string of units when the state of charge of the selected unit is greater than the target state of charge; and

   the power converter transferring energy from the string of units to charge the selected unit when the state of charge of the selected unit is less than the target state of charge.

4.    The system of claim 3, wherein the power converter comprises:

an up converter transferring energy from the selected unit to charge the string of units; and

a down converter transferring energy from the string of units to charge the selected unit.

5.    The system of claim 3, wherein the power converter comprises:

a common transformer that is used as a down converter to transfer energy from the string of units to charge the selected unit when the state of charge of the selected unit is less than the target state of charge; and

the common transformer that is used as an up converter to transfer energy from the selected unit to the string of units when the state of charge of the selected unit is greater than the target state of charge.

6.    The system of claim 3, wherein the circuit further comprises:

plural semiconductor switches selectively coupling the power converter to the selected unit.

7.    The system of claim 6, wherein:

the plural semiconductor switches are bidirectional;

when the state of charge of the selected unit is greater than the target state of charge, a pair of the plural bidirectional switches electrically coupling the power converter to the selected unit to discharge the unit; and

when the state of charge of the selected unit is less than the target state of charge, the pair of the plural bidirectional switches electrically coupling the power converter to the selected unit to charge the unit.

8.    The system of claim 7, further comprising:

a polarity selector connecting the pair of plural bidirectional switches to the power converter.

9.    The system of claim 6, wherein:

the plural semiconductor switches are unidirectional;

when the state of charge of the selected unit is greater than the target state of charge, a first pair of the plural unidirectional switches electrically couples the power converter to the selected unit to discharge the unit; and

when the state of charge of the selected unit is less than the target state of charge, a second pair of the plural unidirectional switches electrically couples the power converter to the selected unit to charge the unit.

10.    The system of claim 3, wherein the circuit further comprises:

a controller selectively monitoring the state of charge of each storage unit; and

the controller directing the power converter to transfer energy between the selected unit and the string of units, such that the state of charge of the selected unit converges toward the target state of charge.

11.    The system of claim 10, wherein the circuit further comprises:

a first sensor detecting voltage and current data of the selected unit; and

the controller utilizing the voltage and current data from the first sensor to monitor the state of charge of the selected unit.

12.     The system of claim 10, wherein the circuit further comprises:

          a second sensor detecting total current data of the string of units;

          the controller utilizing the total current data from the second

sensor to determine the target state of charge.

5     13.     The system of claim 1, further comprising:

          plural strings of electrical storage units coupled in series, each

storage unit having a state of charge;

          corresponding circuits selectively monitoring the state of charge

of each storage unit in a corresponding string of electrical storage units;

10     and

          for each of the plural strings of units, when the state of charge of

a selected unit is different than a target state of charge, the corresponding

circuit transferring energy between the selected unit and the

corresponding string of units, such that the state of charge of the selected

15     unit converges toward the target state of charge.

14.     The system of claim 13, further comprising:

          a master controller;

          for each of the plural strings of units, the master controller

determining a corresponding target state of charge;

20     the controller directing each of the corresponding circuits in

transferring energy between a selected unit and the corresponding string

of units, such that the state of charge of the selected unit converges

toward the corresponding target state of charge.

15.     The system of claim 14, wherein each of the corresponding circuits comprises:

25     a power converter;

the power converter transferring energy from the selected unit to charge the corresponding string of units when the state of charge of the selected unit is greater than the corresponding target state of charge; and

the power converter transferring energy from the corresponding string of units to charge the selected unit when the state of charge of the selected unit is less than the corresponding target state of charge.

16. The system of claim 15, wherein each of the corresponding circuits comprises:

plural semiconductor switches selectively coupling the power converter to each storage unit.

17. The system of claim 13, further comprising:

a master controller determining a common target state of charge;

the master controller directing each of the corresponding circuits in transferring energy between a selected unit and the corresponding string of units, such that the state of charge of the selected unit converges toward the common target state of charge.

18. The system of claim 1, wherein each storage unit is a storage cell.

19. The system of claim 1, wherein each storage unit is a battery module having a string of cells.

20. The system of claim 1, wherein a battery pack comprises a string of one or more storage units.

21. The system of claim 1, wherein the string of units are in a battery module, there being plural battery modules forming a battery pack.

22. A system for balancing state of charge among plural series connected electrical energy storage units, comprising:

a string of electrical energy storage units, each storage unit having a state of charge;

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a circuit selectively monitoring the state of charge of each storage unit; and

when the state of charge of a selected unit is greater than a target state of charge, the circuit transferring energy from the selected unit to a non-dissipative load, such that the state of charge of the selected unit

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converges toward the target state of charge.

23. The system of claim 22 wherein:

when the state of charge of the selected unit is less than the target state of charge, the circuit transferring energy from the non-dissipative load to the selected unit, such that the state of charge of the selected unit

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converges toward the target state of charge.

24. A system for balancing state of charge among plural series connected electrical energy storage units, comprising:

a string of electrical energy storage units, each storage unit having a state of charge;

20
a circuit selectively monitoring the state of charge of each storage unit under a load; and

when the state of charge of a selected unit is different than a target state of charge, the circuit transferring energy between the selected unit and the string of storage units, such that the state of charge of the

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selected unit converges toward the target state of charge.

25. A method for balancing state of charge among plural series connected electrical energy storage units, comprising:

selectively monitoring the state of charge of each storage unit in a string of electrical energy storage units;

5 when the state of charge of a selected unit is greater than a target state of charge, transferring energy from the selected unit to the string of storage units, such that the state of charge of the selected unit converges toward the target state of charge.

26. The method of claim 25, further comprising:

10 when the state of charge of the selected unit is less than the target state of charge, transferring energy from the string of units to charge the selected unit, such that the state of charge of the selected unit converges toward the target state of charge.

27. The method of claim 26, wherein the energy is transferred by a power converter.

15 28. The method of claim 27, further comprising:

selectively coupling the selected unit to the power converter by enabling a pair of plural semiconductor switches.

29. The method of claim 28, wherein the plural semiconductor switches are bidirectional and comprising:

20 when the state of charge of the selected unit is greater than the target state of charge, enabling a pair of the plural bidirectional switches to electrically couple the power converter to the selected unit to discharge the unit; and

when the state of charge of the selected unit is less than the target

25 state of charge, enabling the pair of the plural bidirectional switches to

electrically couple the power converter to the selected unit to charge the unit.

30. The method of claim 29, further comprising:

connecting the pair of plural bidirectional switches to the power converter through a polarity selector.

31. The method of claim 28, wherein the plural semiconductor switches are unidirectional and comprising:

when the state of charge of the selected unit is greater than the target state of charge, enabling a first pair of the plural unidirectional switches to electrically couple the power converter to the selected unit to discharge the unit; and

when the state of charge of the selected unit is less than the target state of charge, enabling a second pair of the plural unidirectional switches to electrically couple the power converter to the selected unit to charge the unit.

32. The method of claim 25, further comprising:

detecting voltage and current data of the selected storage unit; and

utilizing the voltage and current data to monitor the state of charge of the selected unit.

33. The method of claim 25, further comprising:

detecting total current data of the string of units; and

utilizing the total current data to determine the target state of charge.

34.  The method of claim 25, wherein plural strings of electrical storage units are coupled in series, each storage unit have a state of charge, and further comprising:

      selectively monitoring the state of charge of each storage unit in a

5  corresponding string of electrical storage units; and

      for each of the plural strings of units, when the state of charge of a selected unit is different than a target state of charge, transferring energy between the selected unit and the corresponding string of units, such that the state of charge of the selected unit converges toward the

10  target state of charge.

35.  The method of claim 34, further comprising:

      for each of the plural strings of units, determining a corresponding target state of charge; and

      transferring energy between the selected unit and the

15  corresponding string of units, such that the state of charge of the selected unit converges toward the corresponding target state of charge.

36.  The method of claim 34, further comprising:

      determining a common target state of charge; and

      transferring energy between the selected unit and the

20  corresponding string of units, such that the state of charge of the selected unit converges toward the common target state of charge.

37.  A method for balancing state of charge among plural series connected electrical energy storage units, comprising:

      selectively monitoring the state of charge of each storage unit in a

25  string of electrical energy storage units; and

when the state of charge of a selected unit is greater than a target state of charge, transferring energy from the selected unit to a non-dissipative load, such that the state of charge of the selected unit converges toward the target state of charge.

5    38.    The method of claim 37, further comprising:

when the state of charge of the selected unit is less than the target state of charge, transferring energy from the non-dissipative load to the selected unit, such that the state of charge of the selected unit converges toward the target state of charge.

10    39.    A method for balancing state of charge among plural series connected electrical energy storage units, comprising:

selectively monitoring the state of charge of each storage unit in a string of electrical energy storage units, the selected storage unit being monitored under a load;

15        when the state of charge of a selected unit is different than a target state of charge, transferring energy between the selected unit and the string of storage units, such that the state of charge of the selected unit converges toward the target state of charge.